EXTRA-MORAINIC DRIFT IN THE SUSQUEHANNA, LEHIGH AND DELAWARE VALLEYS.

BY G. FREDERICK WRIGHT.

In the autumn of 1880, the late Professor Henry Carvill Lewis and myself began the exploration of what we supposed was the boundary of direct glacial action in Eastern Pennsylvania. The work of field exploration was substantially completed in 1881. Our report constitutes volume Z in the series published by the 2d Geological Survey of Pennsylvania, and appeared in 1884.

After accepting with little question the delineation of the terminal moraine from the New Jersey report for that State, we began work in Northampton County, Pa., and soon succeeded in tracing a well marked moraine across the county from near Belvidere, in New Jersey, to the vicinity of Offset Mountain, in the Kittatinny Range, a few miles northeast of the Wind Gap. At that time our attention was not sufficiently directed to the more dispersed erratics and thinner glacial deposits which usually extend in advance of the moraine, and which, subsequently, we came to recognize as the "fringe." The facts concerning the "fringe" came prominently to light in connection with my own further investigations in the western part of Pennsylvania, and in my own investigation in the States farther west. In my reports on that region I soon ceased to give special attention to moraines, and confined attention to the border of the fringe, and in my map in the volume "The Ice Age in North America," the legend indicating the terminal moraine across Pennsylvania, gives place in the States further west to one marking the southern limit of the ice sheet.

In view of these facts it is significant that in his report (p. 201), Professor Lewis uses this language: "It is possible that traces of this fringe might be detected in Eastern Pennsylvania and in New Jersey. In fact, occasional transported boulders do occur upon several hilltops, just in front of the moraine, in the vicinity of the Susquehanna and Delaware rivers, and in New Jersey, which I find it difficult to explain on any theory of a flood, and which may be of like origin with the fringe as developed farther west. Facts observed by other geologists in more western States, and published since this report was written, confirm my impression that this fringe is destined to play an important part in glacial geology."

To this I have added, in my volume on the Ice Age referred to, the statement that in driving over the country, between New Brunswick and Metuchen, N. J., in company with Professor Cook, I had observed what I considered unmistakable evidence of this fringe a few miles south of the well defined moraine. (Ice Age, p. 136.)

So much it is proper to say to indicate the reasons urging me to re-examine the field where Professor Lewis and I began work on the glacial boundary. This is the more important since Professor Lewis's death has left unpublished a large amount of material in the hands of his executors, which is at present inaccessible. This consists of notes collected upon the terraces of the Atlantic rivers, which he expected soon to publish, and to which he makes occasional reference in Vol. Z, as discussing more fully many topics barely alluded to in that report. Of his views I had much knowledge, from our constant association in the field. For some time past reports of phenomena, seemingly inconsistent with the interpretation which we had put upon the facts, have been gaining currency, but I have not dared to venture any criticism until a personal re-examination of the field had been made. This I have had the opportunity of doing during the past season, and I herewith submit the results for consideration and criticism.

The principal statements which had perplexed me were:—

1st, That of Mr. McGee (Am. Jour. Sci., vol. 135, pp. 377, 378, 381), that from Harrisburg to the terminal moraine at Berwick there are evidences of a submergence during glacial times, which allowed still water deposits to accumulate 500 feet above the present river level.

2d, That of Professor Salisbury, that glaciated stones had been found by him near Sunbury, 600 feet above the river. (Adduced by President Chamberlin, Bul. Geol. Soc., vol. I, p. 473. Reiterated by Salisbury, vol. 3, p. 180.)

3d, Statements of Mr. McGee that there is evidence of a land submergence in the Delaware Valley of at least 400 feet in the vicinity of the terminal moraine. The evidence of this is principally drawn from a section of the valley five miles below Belvidere. (Am. Jour. Sci., vol. 135, p. 379.)

4th, Statements by Professor Salisbury, seeming to imply that evidences of ice occupation are found in New Jersey at High Bridge, Pattenburg and Monmouth Junction, and in Pennsylvania at Falls-

ington, a few miles west of Trenton, and Bridgeport, in the valley of the Schuylkill, a few miles west of Philadelphia.

The principal conclusions arrived at by Professor Salisbury are involved in the following extracts. After having minutely described the deposits at Pattenburg, High Bridge, Oxford Church and Little York, N. J., and the excessive oxidation and disintegration which his supposed extra-morainic drift has suffered at these places; and having expressed the opinion that the phenomena most certainly indicate a glacial period several times older than that with which the terminal moraine is connected, he goes on to say:

"The phenomena here described as indicating a drift-sheet older than that represented by the moraine and the drift north of it, are not confined to Hunterdon and Morris counties. The extent of the territory over which these phenomena occur is not known, though many facts concerning its extension are already in the possession of the Survey. The railway cuts southeast of New Brunswick afford similar evidence in this part of the State. Glacial-striated boulders have also been found between Monmouth Junction and Deans, along the line of the Pennsylvania railway, and at Kingston on the Millstone River, three miles northeast of Princeton, though they are by no means common in either place.

"In Pennsylvania there are drift deposits well south of the moraine in similar situations. Glaciated boulders, imbedded in clay which presents the general aspect of till, have been found near South Bethlehem, several hundred feet above the Lehigh River, and at various other points south of the Lehigh, at distances from the moraine comparable to those at which the corresponding formation in New Jersey occurs. Drift closely resembling till, and containing striated rock material, occurs on the west side of the Delaware, near Fallsington, three or four miles southwest of Trenton, and, with Mr. C. E. Peet, the writer found similar deposits at Bridgeport, Pa., opposite Norristown, still further south. Bridgeport is the southernmost point at which glacially-striated material has been seen by the writer. Glaciated boulderets were here taken from clay of such character that, were the locality known to have been covered by ice, its reference to till would be fully warranted. Bridgeport is about fifty miles south of the terminal moraine.

"It is not intended to convey the impression that every region where glaciated stone may be found was necessarily once covered by glacier ice. The possibility of transportation of glaciated material beyond the edge of the ice by water, is distinctly recognized. But it is not believed that water alone, or water-bearing glacially-derived bergs, could produce all the results which are here recorded. Neither the structure of the extra-morainic drift, nor its physical make-up, nor its geographic or topographic distribution, is consistent with such an hypothesis.

"At several points in New Jersey, south of all the localities thus far mentioned within the State, there are topographic features which are easy of explanation if ice once extended to the region where they occur, but which seem to be very difficult of explanation on any other hypothesis. The features here referred to characterize the region from Washington, Middlesex county, southwest to Fresh Ponds and beyond, and also the region east of Trenton, from White Horse to Hamilton Square. The topography in these regions is very much like that of a subdued terminal moraine.

"The determination of the southern limit of ice action during the earlier glaciation is likely to be a matter of some difficulty. In its southern extension the ice reached the region of the 'yellow-gravel' formation." (An. Rep. of State Geologist for the year 1891, pp. 106, 107.)

It is fair to say that Professor Salisbury informs me that he does not now think the ice of "the first glacial period extended farther south than High Bridge and Pattenburg," and would direct special attention to the paragraph quoted, in which he speaks of the possibility of transportation of glacial material by water. But as we have to deal with the report as it stands, it is necessary to call attention to its natural interpretation as it falls into the hands of the ordinary reader, in order to correct the errors into which he would be unwittingly led. Such a reader must be informed that when Professor Salisbury speaks of extra-morainic drift extending to the "yellow-gravel" (in quotation marks), he does not mean the yellow gravel as it is marked upon the latest map of the New Jersey Survey, but some yellow gravel which he has discovered a considerable distance farther north. In his paper before the Geological Society, however, he uses language which cannot so easily be explained, saying that boulder clay similar to that at High Bridge and Pattenburg, and whose existence must be explained in the same way, is found south of Pattenburg to a distance fully twenty miles south of the moraine. In the same paper he also speaks of a locality "fifteen miles southwest of New Brunswick," where phenomena are exhibited which present evidences of direct glacial action.

In the light of my investigations this summer, I think I am able to detect the cause of the conflicting statements of facts by these eminent observers, and to eliminate some very serious errors of interpretation which one or other of them has brought into the discussion.

As I had surmised, and repeatedly urged in publications upon the subject, the cause of the error is to be traced to the undue

emphasis which was at first placed upon the terminal moraine as marking the southern limit of the area occupied by ice during glacial times. Into this error Professor Lewis and I fell at first equally with others, though I believe my experience led me to free myself from it sooner than most others. The fact is that in Eastern Pennsylvania, and in portions, certainly, of New Jersey, the "fringe" does extend a considerable distance beyond the terminal moraine. In the Susquehanna, the southern limit of the ice was several miles below Berwick. While the Delaware Valley was occupied by a lobe of the glacier, which extended in the axis of the valley to the Musconetcong range, five or six miles southeast of Easton, and about fifteen miles south of Belvidere, which has heretofore stood as the limit. The supposed evidences of a farther extension of the ice southward are readily explained, in a manner which I will presently detail. The evidence upon which these conclusions are based is as follows:

1st, as to the Susquehanna terraces: I began my investigations at Harrisburg. Here I had the advantage of the minute local knowledge of Dr. Harvey B. Bashore, of West Fairview, who had been in correspondence with me concerning the terraces of the vicinity for more than two years. The terraces are for the most part situated in the city of Harrisburg, and Dr. Bashore has scoured the country far and near, and speaks with no ordinary authority upon the subject. I visited the principal points with him, and am prepared to endorse his concise statement of the case which he has written out for me at my request.

"The first terrace at Harrisburg is 28 feet above low water (290 A. T.) upon which Front street is mainly built, and is composed of clay suitable for brick-making, and contains many boulders of large size (4 to 5 feet in diameter), composed of conglomerate and sandstone from the mountain, through which the river has cut a gap a few miles above. This deposit is distinctly marked on both sides of the river.

"The second terrace is 46 feet above the river, but it is not plainly marked. Third street, however, is in a great measure built upon it. This bed is composed of gravel, which has in it some granite and gneiss, and contains large and small boulders all rounded, and is capped by two to three feet of fine loam.

"The third terrace is 90 feet above the river, and forms the plane of Sixth street and part of Fifth. This deposit, which gives a good perpendicular exposure of 15 feet, is composed of fine gravel, some portions of which are granite and gneiss. A few boulders appear in it, from two to three feet in diameter. All are well rounded, and

the whole is capped by from four to five feet of fine clay. Almost all of the boulders occur in the gravel.

"From this terrace the slope is gradual down to Paxton Creek, on the opposite side of which a slate hill (Allison Hill) rises very abruptly, and is covered on the top by the fourth terrace.

"The fourth terrace is 130 feet above the river, 420 A. T. At Walnut and Herr streets there is a very good exposure showing the gravel resting upon the slate.

"The thickness of the deposit is about 20 feet, and it is capped by fine brick clay. The gravel bed, especially at its upper part, presents a peculiar white appearance compared with the overlying clay—the line of junction between the gravel and the clay being very distinctly marked. Some rounded boulders occur in it two to four feet in diameter, mostly in the gravel. I found one, however, in the clay. The gravel contains a few pebbles of granite and gneiss, but none were found more than two or three inches in diameter. Above this point (420 A. T.) I could find no positive evidence of water action, although I carefully examined all the surrounding hills and mountains north of Harrisburg."

The occurrence of granitic pebbles in these terraces is of great significance, since it fixes them as contemporaneous with, or subsequent to, the glacial period, for there is no outcrop of this material anywhere in the watershed of the Susquehanna above Harrisburg. The only way the granite could have come wthin reach of Susquehanna floods was by ice transportation into its headwaters, from Canada or the Adirondacks. This upper terrace, therefore, corresponds with Mr. McGee's Columbia formation.

In following up the river I went above the first three ranges of mountains to Dauphin, and drove over Fourth Mountain to Halifax. Near the mouths of the small valleys occupied by Clark and Armstrong creeks, there are terrace accumulations up to about 150 feet above the river, composed for the most part of rounded material, which might have been brought down the creeks. But at higher levels there were no terraces. This was a drive up the river of about fifteen miles, and took us gradually over two slopes, reaching about 900 feet above the river.

We next went up the river to Selinsgrove, about six miles below Sunbury, and examined the country for a few miles east of the river. Here we found the rounded pebbles of the terrace deposit ceasing abruptly at a height of about 200 feet above the river, or about 650 feet above tide. This corroborates Professor I. C. White's observations, as recorded in G 7 p. 363 of the 2d Pa. Report.

Then ascending the river to Sunbury, we drove some miles east toward Klinegrove, by a route which took us over a typical variety of high and low land, then westward some miles back of Shickilimy, then up both branches of the Susquehanna to Montour's Ridge, and over the higher land intervening. The result was to convince us that about 200 feet limits the deposits of pebbles which can be in any way connected with terraces of the present river, and that there were absolutely no deposits that could reasonably indicate the presence of land ice over that region at any time. A boulder of gneiss one foot in diameter is reported from the fourth terrace at Northumberland, 175 feet above the river. (G 7, p. 336.)

We then ascended the river to Bloomsburg, and drove westward to join the line of Lewis's terminal moraine near Knob Mountain, a mile or two north of Orangeville, in Columbia County. Here we found extensive terrace deposits in the valley of Fishing Creek, rising something more than 100 feet above it. We also found considerable deposits of transported boulders on the hills north of Lightstreet, extending in a practically continuous sheet from the terminal moraine which Lewis had located on the farm of Wm. Beck, two miles north of Orangeville. Without much question the ice extended here on the hills west of the river almost as far southwest as Bloomsburg, and covered to a height of from 300 to 400 feet above the river, the projection of Montour's Ridge which extends northeastward from the city. (See G 7, p. 256.)

A drive over the uplands on the east side of the river as far as Mifflinville, showed that there was nothing which could be attributed to glacial action over that area until reaching a point about two miles south of Mifflinville, where a few conglomerate boulders and some scratched stones appeared about 500 feet above the river. It is perhaps possible that these may have been derived from the higher outcrops on Nescopec Mountain, two or three miles to the east. But they now rest on the surface of Hamilton slate, and are separated from the mountain by a valley of considerable depth, eroded by a small creek. So scarce, however, are these remnants of the ice age that they escaped the eagle eye of Professor I. C. White. (G. 7, p. 278.) But in view of the abundant signs observed by him, as well as by myself on the other side of the river, I have little hesitation in bringing the border of the glacial field on the south side of the river, down to the west boundary of Mifflin township. Professor White is also probably right in opposition to

Professor Lewis in bringing the ice border down to Green Creek on the north side of Knob Mountain, in Orange township. (G. 7, p. 217.) Thus it appears that the section between Bloomsburg and Berwick (Am. Jour. vol. 135, pp. 376, 464), upon which Mr. McGee depends for proof of his Columbia submergence of 500 feet in this region, is within the attenuated border or fringe, as I had surmised, and hence fails to prove what he supposed.

On passing over into the valley of the Lehigh, we first drove from the Glen Summit Hotel to Hazleton, during which we satisfied ourselves that there are no glacial deposits much farther south than the terminal moraine, as there marked by Professor Lewis at Drums, where a short distance to the south, the outcropping coal measures form a bold obstructing wall several hundred feet above the valley of Nescopec Creek. But the region beyond is so broken up by mining operations, and with the disintegrating debris of the Pottsville Conglomerate, that I should not put entire confidence in such investigations as I was able to make.

In the broad anticlinal valley crossed by the Lehigh, between Mauch Chunk Mountain and Blue Ridge, however, the opportunity for crucial tests is as good as could be desired. Here we found that the evidence of direct occupation by glacial ice extended at most only a few miles beyond the moraine, as marked on Lewis's map. Extensive drives up the valley of Big Creek, near the mountain north from Weissport, across the valley both of Big Creek and Aquanchicola Creek to the Lehigh Water Gap, as well as south from Lehighton, up and across the valley of Mahanoy Creek, demonstrated to my satisfaction that glacial ice had never extended to within ten miles of the Lehigh at this point. At Lehighton, however, there is a well defined pebbly terrace rising about 75 feet above the river. The material is well rounded, and mixed with yellow sand and clay. These terrace deposits do not appear above that level anywhere between Lehighton and the Water Gap, either on the Lehigh or on its tributaries. But on the gentle slopes of Mauch Chunk and Big Creek Mountains there are many pebbles which have evidently been brought down in the slow process of erosion. These are collected at various heights in special quantity in front of the openings into the mountains effected by the side streams, and in many cases clearly represent ancient deltas when the whole drainage was at a higher level.

East of the Blue Ridge I was joined by Professor A. A. Wright, who had been spending the summer at Flemington, N. J., and who at my request had been giving attention to the deposits near by, at High Bridge and Pattenburg. Hence I will begin with the conclusions concerning those deposits so fully described by Professor Salisbury and classed by him as glacial. And certainly at first glance they do look enough like glacial deposits to "deceive if it were possible the very elect." That in this case it is possible, I think is proved by the fact that they have probably deceived Professor Salisbury. As described so well by him (N. J. Geol. Sur. 1891, p. 103), these deposits show only slight signs of stratification, and contain, mingled through the clay to a depth of from ten to thirty feet, many boulders large or small, some of them several feet in diameter, and most of them partially rounded. There are also many smaller fragments of slate, nearly all of which are scratched. One well scratched fragment, about two feet long and one and a half wide, was observed well scratched on one side. At Pattenburg also we found two or three of the boulders of harder rock somewhat scratched. But such are very rare, and the rounding was not quite characteristic of a glaciated region.

A noticeable, and I believe, a crucial fact in determining the character of the deposit, is that the material is local. The boulders are all of a gneissoid character, such as compose the mountain which in both places rises several hundred feet above the deposits directly to the north, and down which boulders of the same sort are creeping in majestic array in every direction. I did, however, at High Bridge, note one small pebble which was possibly Potsdam sandstone. Furthermore these mountain flanks were doubtless once covered with strata of limestone and slate, such as are still found in close proximity in the synclinal basins which have escaped erosion. Hence it is possible, if not probable, that the fragments of slate are the remains which have escaped absolute destruction by the erosive agencies which have been so long at work in this whole region. The scratches might well have been made in the process of creeping down the disintegrating mountain side, which secures almost exactly the same mechanical forces as the movement of a glacier does.

Creep scratches engaged the attention of Professor Lewis and myself at the outset of our investigations in Pennsylvania in 1881, and are discussed at considerable length both on p. 96 of vol. Z, in the account of phenomena at Hickory Run, in Carbon County, and in

other places. They were also noticed on the slate rocks at Bangor. I have taken pains this summer to revisit some of these places, and am more than ever impressed with the fact that a small scratched surface, and a limited number of scratched pebbles do not prove a glacial period. Near Ackermansville, in Northampton County, Pa., I observed excellent striæ on the slate rock in a railroad cut, made by the loose material which has slid down the bank since the cut was opened a year or two ago. I also succeeded in securing well marked scratches on slate pebbles by an artificial slide which I myself produced in the bank at Pattenburg.

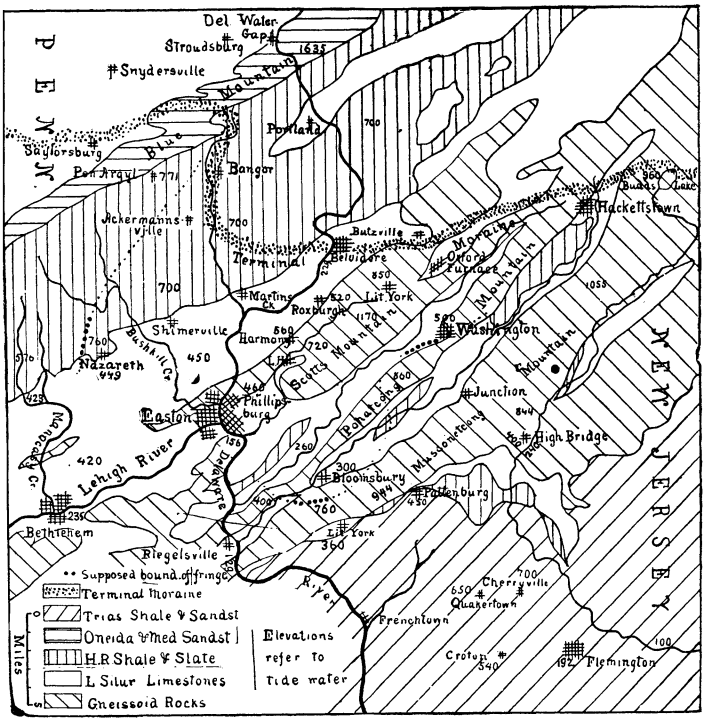
It is fair to say, however, that we found evidence of the true fringe of the ice age so near to both High Bridge and Pattenburg, that it is not much of a strain on the scientific imagination to suppose that the ice here just crossed over Musconetcong Mountain and ended for a while at these points. But that this was not the case, I think is evident from the considerations following:—

1st. The cause already adduced is entirely competent to produce the results. There is no occasion to introduce a greater cause.

2d. The absence, as just stated, of all material foreign to the immediate locality, demonstrates the local character of the cause.

3d. The appearance of foreign material as an overwash gravel in the valley of the Musconetcong River, eight or ten miles to the northwest just beyond Junction, shows that foreign material would have been brought by glacial ice, had it extended so far. Here pebbles of the enduring and well defined Medina sandstone, and Oneida conglomerate, appear to a considerable extent, derived probably from the moraine to the northeast, in which it has its headwaters. But on the low summits of the parallel Pohatcong Mountain, south of Washington, we failed to find any foreign material in two cross sections which we made under favorable circumstances. In the valley of the Pohatcong, at and below Washington, however, the foreign material is so abundant and of such size as to make it probable that the glacial ice overrode Scott's Mountain. Boulders of the Medina and Oneida sandstones occur here south of Pohatcong River, in connection with a deposit of large extent of finer material capped with loam and clay. The railroad also makes two other good sections in till south of the mountains. From this point on to the north these characteristic foreign boulders are found at frequent intervals on the road leading up the south side of Scott's Mountain toward Oxford Furnace, to a height of 360 feet

above the river. These boulders increase in abundance on the north side, but are mingled in irregular fashion with the disintegrated material of the gneiss of which the mountain is constituted. It is this disintegrated local material, both here and at High Bridge and Pattenburg, I presume, which Professor Salisbury has attributed to an earlier glacial epoch. Two or three miles farther north begin the accumulations which have been called the terminal moraine. It is important to notice that there is continuity in the distribution of this foreign material from the moraine southward over Scott's Mountain into the valley of the Pohatcong at Washington, but that the continuity seems to be broken at the low ridge of Pohatcong Mountain.



On going farther west this same continuity in the distribution of foreign material in front of the moraine occurs down to an equal and even longer distance south. The Medina and Oneida boulders are very abundant at Little York, which is near the summit of

Scott's Mountain, (400 feet above the river Pohatcong, and 600 above the Delaware), and continues to Brass Castle, on the Pohatcong. On going still farther west, we found the same continuity of foreign boulders extending through Harmony over Marble Mountain, a projection of Scott's Mountain, while the plain bordering the Pohatcong Creek was deeply covered with Medina and Oneida boulders down to the vicinity of Phillipsburg. These must have been derived from the deposits which had been brought over from Scott's and Marble Mountains by glacier ice. Going still farther south on this line within five miles of the Delaware, we found Medina and Oneida boulders all along to the summit of a col on Musconetcong Mountain, two or three miles west of Bloomsbury, and at a height of something over 500 feet above the river. Here a boulder of Medina was found measuring 3x2½x1 feet. Another still retained a very perfectly scratched surface.

The other portions of the mountain here rose about 200 feet higher than this col, and upon them we failed to find foreign boulders. But on following down a small stream leading south to another Little York on Hikihokake Creek, bordering the Triassic shales, which here begin, we found many pebbles of Medina sandstone distributed about its ancient delta. But they did not extend far out on the Triassic deposits. A long detour upon these showed that they were perfectly free from foreign material. Though flanking the gneissoid rocks of Musconetcong Mountain, which rises several hundred feet above them, there has been no southern transportation of material over that area since the original deposition of the Triassic period. This seems to prove conclusively that glacial ice once extended within five miles of the Delaware River, as far south as the summit of Musconetcong Mountain and no farther.

Some facts in confirmation of this inference occur at Pattenburg, which is just over the watershed to the east, leading into the Raritan River, and not more than seven miles distant. The supposed glacial deposit there lies near the headwaters of Mulhockaway Creek, which in the upper part separates the gneissoid rocks of Musconetcong Mountain from the Triassic rocks to the south. The Triassic rocks rise upward of 400 feet above the stream on the south, while the gneissoid rocks rise about the same height on the north. The Triassic deposits are here of a conglomerate character, often containing pebbles a foot in diameter, some of which seem to have been

derived from the Medina group. Some of these occurred near the Pattenburg cut, and at first deceived us. But subsequently we found portions of this Triassic conglomerate in places in the cut, and satisfied ourselves that there was nothing but local material there. The gneissoid rocks have worked into the valley faster than the Triassic, but at the same time the stream has cut down deeper on the side occupied by the gneiss rock. There has been no intermingling of material as there must have been had glacial ice covered the whole area. Musconetcong Mountain was the limit of glacial action east of the Delaware River and west of Bloomsburg.

These inferences are confirmed by the absence of evidences of the action of land ice in the country on both sides of the river south of this point. From Riegelsville, near the mouth of the Musconetcong River, we drove to Bursonville, several miles out over the Triassic plateau which there extends beyond the Archæan outcrop, which rises several hundred feet on the south of the Lehigh, and where, if there had been any southern transportation by land ice, the remains would be most likely to be seen. But there was not the least sign of foreign material to be found. We drove out on both sides of the river at Lambertville, some distance down toward Trenton, with the same result. Professor A. A. Wright drove from Flemington across Sourland Mountain with the same result.

Along the Delaware we found distinct terraces both of Trenton and Columbia gravels. At Riegelsville the Columbia was well developed in an extensive terrace, preserved in an ox bow of the valley at a height of 175 feet. It had all the characteristics of the Brick Clays and Red Gravel at Philadelphia and other places below.

In addition to these detours we took the ride along the North Pennsylvania Railroad, from Bethlehem to Philadelphia, which passes over Mesozoic deposits for a distance of 25 or 30 miles, and shows almost a continuous section of the surface soil. There is no foreign material in it or on it. The same is true in New Jersey in the sections shown on the railroad from South Plainfield to Flemington, and from Bound Brook to Trenton.

The deposits at Fallsington belong to the Columbia. They are related to the river level, and are not higher than those at Philadelphia. The occurrence of scratched stones in them simply teaches that floating ice can transport material without effacing all scratches. At Bridgeport, opposite Norristown, on the Schuylkill River, there

is a terrace scarcely 100 feet high. I very much question whether there are any "glaciated" pebbles in it. Certainly the whole country around through which we drove for a considerable distance, does not show signs of glacial action. I should say that the occurrence of scratched stones in that vicinity conclusively proves that such striation can be produced by other causes than glacial ice. The same is, perhaps, true of Professor Salisbury's other isolated cases at Bethlehem and Sunbury, and probably support my inferences concerning the deposits at High Bridge and Pattenburg.

The conglomerate boulders between Monmouth Junction and Deans are not over 100 feet above sea-level, and there is no higher land between them and the Delaware at Trenton. They may, therefore, easily have been floated into their present position during the flooded condition of the lower Delaware Valley, when the deposits of Philadelphia red gravel and brick clay (the Columbia) took place.

The facts already presented concerning the extension of glacial ice on the east side of the Delaware River for several miles south of Easton, furnish the key to the perplexing phenomena of the Lehigh Valley below Bethlehem. The fringe of glacial ice deposits extends southward to the vicinity of Easton, and westward to the divide between Bushkill and Monocacy creeks in the vicinity of Nazareth. The evidence is not yet as complete as I would like, but there is already enough to give a great degree of certainty.

It is significant that Monocacy Creek north of Bethlehem is perfectly free from pebbles—the natural reason being that it has its course over limestone and slate formations which furnished none. If these formations had been overrun by glacial ice, this would not have been the case. On the other hand, Bushkill Creek has them in abundance. The only difference between the creeks is that boulders had been scattered over the headwaters of the Bushkill by the ice, and not over those of Monocacy. That the ice extended nearly, at least, to the watershed between the creeks seems certain, from the fact that large boulders of Medina occur in considerable abundance on the slate hills two miles north of Nazareth, at a height of about 400 feet above the Bushkill.

The Lehigh, from the Gap to Easton, flows through or across the Hudson River Slates and Trenton Limestone, which so persistently border the Blue Ridge all along the Atlantic coast. For some reason, the surface of the limestone belt is pretty generally from 200

to 300 feet lower than the slate. Indeed the limestone is rarely more than 200 feet above the river. Hence it is within reach of the regular Columbia deposits. It is therefore difficult to tell whether the distribution of glaciated material over this area about Bethlehem and toward Easton was by direct glacial action or by the aid of water. The extension of the ice past the mouth of the Lehigh would indicate a good deal of disturbance in the drainage of the river, and I am inclined to recognize that agency in accounting for many of the facts. The terraces at Bethlehem are not over 200 feet above the river. If, however, it be true that Professor Salisbury has found glaciated pebbles 500 feet above the river on the mountain south of the city I should grant the extension of the glacier to that point. But such an extension seems to me improbable, from the lay of the land. The glacier which surmounted Blue Ridge at Offset Mountain, and in its retreat piled up the vast moraine at Ackermansville, may well have fanned out to cover the hills north of Nazareth, and it certainly deposited a moraine of considerable dimensions near Shimerville, about five miles north of Easton. But it seems unlikely that it could extend as far as Bethlehem, and since we have other causes in the field to easily account for all the facts that appear there, we need not make the supposition. Floating ice in a river valley gorged as this was both by bergs from the glacier further up, and by land ice at its mouth, is cause sufficient, and there is no need of asking for more.

The conclusion of the whole matter is:—1st, That on the Atlantic coast, as in the Mississippi Valley, there is usually a fringe of thinner glacial deposits extending a few miles more or less, south of any well defined moraine. 2d, That this fringe is limited in the east branch of the Susquehanna by Montour's Ridge at Bloomsburg. That all the higher glacial deposits below that point belong to the Columbian era, and do not extend anywhere much above 200 feet above the river, while at Harrisburg they are limited to about 130 feet. 3d, That in the Delaware Valley the ice extended about six miles past the mouth of the Lehigh, and for several miles northeastward was limited by Musconetcong Mountain, and then drew back to the rear of Pohatcong Mountain. Farther east, however, these mountains both come again into the range of the ice movement. 4th, That the lower part of the Lehigh was specially clogged with ice, so as to increase the floods for some distance up toward the Gap, but the ice

did not pass over South Mountain into the Triassic plain of Bucks County. 5th, That below this moderate fringe there is no evidence of direct glacial action, but every evidence against it, except possibly at High Bridge and Pattenburg. 6th, The important thing to do now is accurately to delineate the border of this fringe by the aid of the easily recognizable transported foreign material. Since last summer I have been able to determine the limit approximately a few miles south of Draketown, near German Valley, about half way between High Bridge and Dover. A few days' work would, I am confident, determine the line entirely across the State. 7th, The deposits mentioned by Professor Salisbury at Fallsington, in Pennsylvania, and at Monmouth and Kingston, in New Jersey, consist of material which has been distributed by the floods coming down the Delaware River, while those at High Bridge and Pattenburg possibly belong to the fringe, but more probably to movements connected with the secular disintegration of the gneissoid mountain core, at whose southern base they now lie. 8th, That the facts do not lend support to the theory of a discontinuity between the drift north of the moraine and that south of it. Instead of holding with Professor Salisbury that the drift under discussion has "not had any genetic connection with the moraine, or any time relation to it, except one of great separation" (N. J. Ann. Rep. for 1891, p. 105), we should hold that it had both a genetic connection and a moderately close time relation. It is not true that the extra-morainic drift is, as Professor Salisbury says, "composed of materials which are, in some measure, inherently unlike those which compose the moraine." The drift material is essentially the same. The material in it "inherently unlike those which compose the moraine," comes from the gneissoid rocks with which it is mingled, and which have been undergoing disintegration for untold ages. The "advanced stage" of "oxidation, leaching, disintegration," apparent at Little York and the other places mentioned by Professor Salisbury, is plainly due to preglacial, rather than to postglacial influences. We cannot, therefore, with him hold "that this extra-morainic drift represents the remnant of a drift-covering once more extensive and more uniformly present than now, and that, . . . it was formed . . . by an ice sheet which overspread New Jersey much earlier than that which made the terminal moraine, and the main body of drift which lies north of it." (N. J. Ann. Rep. for 1891, p. 105.)